Upper Extremity Replantation – A Review

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Abstract: Summary: BACKGROUND: In the early 1970s, replantation surgery became an important addition to the armamentarium of reconstructive surgery. In view of the heavy institutional commitment, it became quickly obvious that this type of advanced surgery cannot be performed in all places as occasional surgery. METHODS: This article provides a review of the evolution of upper extremity replantation over the past 20years with regard to indications, basic surgical techniques, and final results. RESULTS: Thirty-eight major upper extremity replantations have recently been analysed and compared with 182 replantations performed 20years ago, using the same data and the same format in both series. No significant differences could be found between these two groups. Analysing this 20-year period, one finds that few changes took place. The only major change that could be ascertained was a significant decrease in the number of replantations in Switzerland due to improved safety measures for working with dangerous machines. Most probably this is true in general for all highly industrialized countries. CONCLUSIONS: Replantation of the upper extremity is a well established method in the treatment of amputation injuries that has a substantial socioeconomic impact. These replantation procedures are very demanding: special skills and experience of the surgical team is the basis for excellent long-term functional results

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Current Strategies of Hand Surgery – Part II

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Upper Extremity Replantation – A Review

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Keywords: Microvascular techniques – replantation – upper limb.

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Replantation der oberen Extremität – Eine Übersicht

Zusammenfassung: Grundlagen: Zu Beginn der 1970iger Jahre wurde die Replantation zu einem wichtigen Instrument in der rekonstruktiven Chirurgie. Durch den beträchtlichen organisatorischen Aufwand wurde bald klar, daß diese aufwendige Chirurgie nicht in allen Abteilungen sinnvoll durchgeführt werden kann.
Methodik: Es wird die Entwicklung der Replantationschirurgie der oberen Extremität der letzten 20 Jahre als Übersicht dargestellt.
Ergebnisse: 38 Replantationen der oberen Extremität wurden kürzlich analysiert und mit einem vergleichbaren Kollektiv von 182 Replantationen, die vor 20 Jahren untersucht wurden, verglichen. Dabei war erstaunlich, daß sich während dieser Zeit hinsichtlich Indikation, chirurgischer Techniken und erzielten Resultaten nur wenig verändert hat. Dagegen ist in der Schweiz und wahrscheinlich auch in anderen hochindustrialisierten Ländern die Anzahl der Replantationen dramatisch gesunken. Dies wird auf die verbesserten Sicherheitsmaßnahmen bei gefährlichen Maschinen zurückgeführt.
Schlussfolgerungen: Die Replantation der oberen Extremität ist eine etablierte Methode zur Behandlung von Amputationsverletzungen, die sich auch im sozioökonomischen Bereich positiv auswirkt. Die Replantationstechniken sind sehr anspruchsvoll: spezielle Fertigkeiten und Erfahrungen des chirurgischen Teams sind Grundlagen für ausgezeichnete funktionelle Langzeitergebnisse.

Introduction

In the early 1970s, it became clear that replantation surgery would become an important addition to the armamentarium of reconstructive surgery (14). Because these procedures are very demanding, not only with regard to the long operating time, special skills and experience of the surgical team, but also with regard to the heavy institutional commitment, it became quickly obvious that this type of surgery should not be performed in all places as occasional surgery. Instead, highly specialized surgeons should form replantation teams working in an appropriate setting, i.e. in a replantation centre where all the required infrastructural resources necessary for replantation surgery can be provided around the clock, 365 days a year. This includes operating room capacity (also for revisional surgery, if necessary), long-term anaesthesia, intensive care unit, specialized hand therapy, microsurgical training laboratory, etc. In 1981, *Burton* et al. outlined the necessary prerequisites to be fulfilled by a replantation centre (2). Looking back, it is amazing how few changes have taken place during the past 20 years with regard to indications, surgical techniques and strategies, and even final results. There have been some refinements in replantation of very distal parts (5, 26), some creative suggestions to combine free composite tissue transplantation in some special situations, the use of improved methods of skeletal management, primary tendon and muscle transfers in complex major replantations, more selective repair in distal nerve stems, and the new possibility of end-to-side nerve juncture; but the quality of microsurgical techniques today is very much the same as what we had already achieved some 20 years ago.

Today, it is unlikely that further efforts to improve microsurgical techniques would yield substantial improvements in the final results.

The main problem we are confronted with is still the often disappointing outcome of nerve repair. Beginning in the 1960s, it was especially *Millesi* et al. who, based on experimental work, initiated substantial improvements in the clinical results of peripheral nerve repair (18).

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We have to assume that the next comparable step forwards will most probably come from research in molecular medicine and not from modifications in microsurgical techniques. However, what really has changed in replantation surgery in the well-industrialized countries, e.g. in western Europe, is the fact that the number of replantation cases has decreased dramatically.

In our institution, this decrease has reached 50 % in just 10 years. Concomitantly, the pattern of amputation injuries has also changed very much. So-called 'guillotine-type' amputations, especially of major parts, have almost disappeared. This is due to the great improvement in safety measures for working with dangerous machines. Today, severe crush and avulsion amputation is – with few exceptions – the predominant type of injury. Such injuries often do not lead to complete severance of the part but often necessitate restoration of the vascular system for survival. These cases, however, are often more demanding for surgeons than the replantation of a guillotine-type amputation.

Replantation surgery has been the pacemaker for free microvascular composite tissue transplantation. It used to be replantation work that provided constant exposure to and training in clinical microvascular work. Today, free microvascular composite tissue transplantation represents by far the most important part of clinical microvascular activity in many institutions. In our institution, the number of cases of free microvascular composite tissue transplantation is more than three times higher than that of replantation cases. In the following, the parameters for indications and basic technical aspects have been reviewed and updated.

Nomenclature

In order to avoid any confusing discussion about the significance of remaining tissue bridges in cases of incomplete severance, one should summarize under the heading of replantation only cases of complete severance or cases that are transformed during debridement from incomplete to complete severance. Only on this basis is a comparable assessment of replantation results possible (3). Cases of incomplete severance may need restoration of the disrupted main vascular system for survival or if the viability of the part distal to the lesion is not at risk, however, despite of this, some vascular anastomoses are performed aiming for improvement of the final result, we use the term revascularisation for survival.

Accordingly, we classify these cases into two groups: (1) revascularization for survival; (2) revascularization for improvement. These two groups must be excluded from an analysis of functional results after replantation.

Indications

In general, replantation should be considered in those cases where the anticipated result will most probably lead to a substantial benefit to the individual patient. However, the risks of a replantation procedure and the extent of the necessary postoperative treatment should reasonably relate to the expected benefit (1, 3, 4, 6, 12). The points detailed below are of particular importance.

General condition of the patient

Special attention must be given to concomitant injuries, local pathologies, obliterative vascular disease, sequelae of previous injuries, and any systemic disease.

Serious associated injuries that may be potentially life threatening must be looked for and adequately treated before embarking on a lengthy replantation procedure.

Especially with arm amputations, associated injuries may be suspected such as fractured ribs, haemato-pneumothorax, and intra-abdominal injuries, e.g. ruptured spleen or liver.

Also, a severe mental handicap may be a contraindication.

Age

The age of the patient must be addressed biologically rather than chronologically. Elderly patients in good physical condition may substantially benefit from replantation especially if level and type of injury are favourable (14).

In general, however, functional results in patients beyond the age of 50 become progressively less favourable. After the age of 60, replantation should be performed only exceptionally.

Children are prime candidates for replantation due to their amazing potential for nerve regeneration and sensory self reeducation, rapid bone healing, and low tendency towards joint stiffness, tendon adhesions and cold intolerance.

If the epiphyseal plates are not damaged, bone growth after replantation is near normal. If the epiphyseal plates have been subject to any considerable damage, however, the foreseeable growth defect and its aesthetic and functional consequences must be fully taken into account in establishing the indication (7, 8, 10).

Occupation

Replantation of a long finger segment can be of crucial importance e.g. to a musician, an actor or a model. The aesthetic aspect of the hand requires due consideration. Apart from the face, the hand is the most exposed part of the body and therefore constantly presented to the curiosity of the public.

On the other hand, an unskilled manual worker or tradesman frequently working outdoors throughout the year may be badly served by such a replantation, as cold intolerance may prove a considerable handicap to him in his work during the cold season.

Patient-relevant information

There is no doubt that in many cases it will be difficult to fully comprehend and assess every aspect of the occupational situation of a patient before the operation. In borderline cases, however, it is senseless and unacceptable to leave to the patient the decision of whether an attempt to reattach a severed part should be made. At the time of the decision, the patient is under mental shock and should not be asked to decide. In all cases, it is the most experienced surgeon of the team who should explain the proposed treatment to the patient and make sure that he or she also understands that postoperative hand rehabilitation may be difficult and will take a long time. Information must also be given on secondary surgery that may be necessary. This will strengthen the patient's motivation for subsequent therapy and also increase his or her confidence in the surgical team. Moreover, the patient must know that the final decision regarding replantation can in some cases only be made during the operation.

Type of amputation injury

A thorough knowledge of the mechanism leading to amputation injury is very important. This will not only make it easier to assess the amputation as such, but also provide indications as to possible major associated injuries. Where machines have

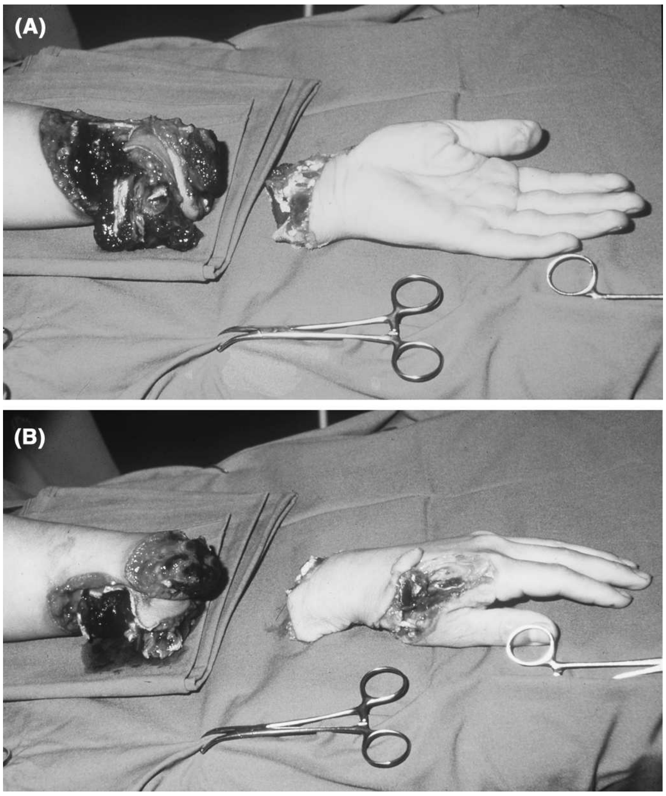

Fig. 1. (A, B) Crush amputation in a 19-year-old manual worker. Replantation with total primary repair of all important structures could be performed after extensive skeletal shortening of 12 cm. Result see Fig. 2.

been involved, it is useful to know the type of the machine, e.g. distance of rollers if these caused the amputation, any unusual heat and/or chemical factors to which the injured parts may have been exposed, etc.

The amputated part must have a certain minimum degree of physical integrity for reattachment to be feasible.

If the amputated segment cannot be replanted, one should bear in mind to possibly use parts of it, such as skin, bone, nerves, vascular grafts or even composite tissue blocks for free microvascular transplantation, in order to achieve the best possible functional restoration for the patient.

It has proved useful to classify the type of injury into four groups: guillotine-type amputation, crush amputation with local tissue damage, crush amputation with extensive tissue damage, and avulsion amputation (3).

Guillotine-type amputation

If the amputated part is not damaged from anoxia, tissues are normal except for those on the cut surface. Only minimal debridement is required, and the prognosis for survival is excellent.

Crush amputation with local tissue damage (see Fig. 1)

There is limited mechanical tissue damage proximal and distal to the amputation site such as caused by mechanical presses with destruction of a segment of the extremity. These injuries require more extensive debridement; accordingly, the part will be shortened. However, prognosis for survival is still very good because debridement will in fact transform the crush amputation into a guillotine-type amputation.

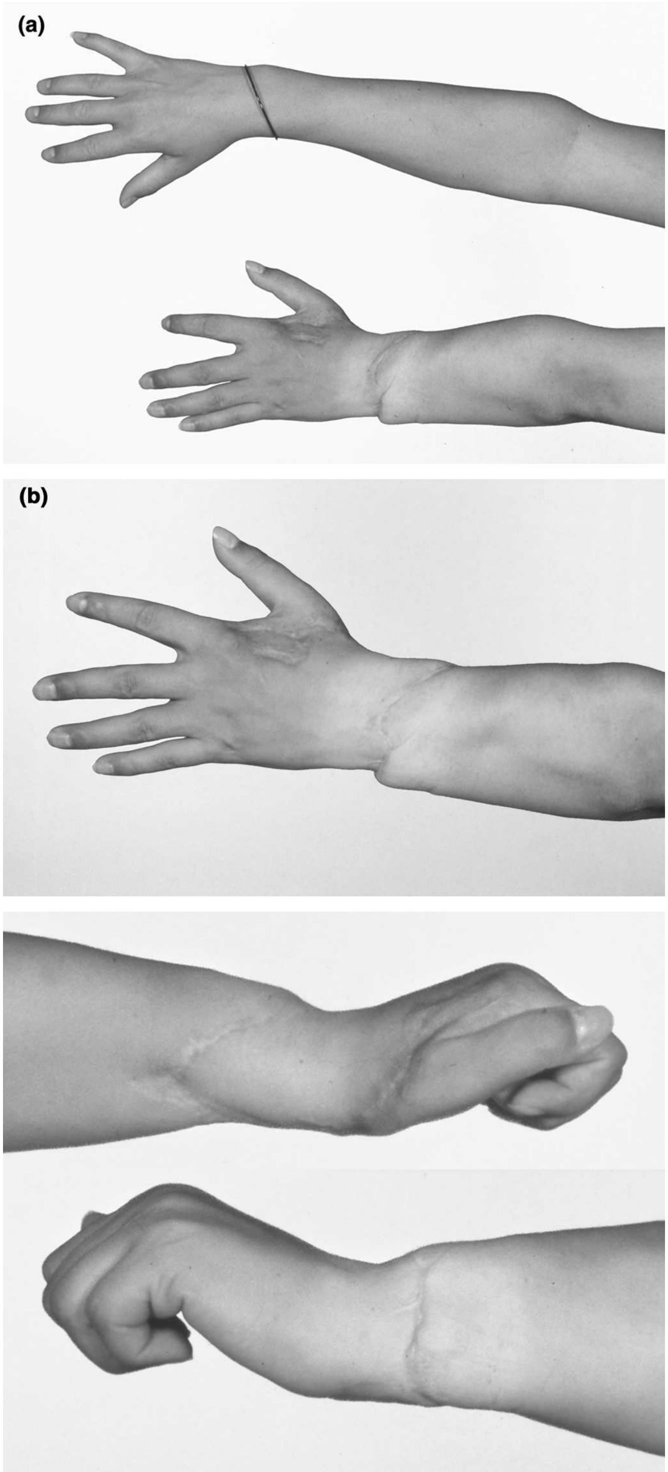

Fig. 2. Long-term result at 12 years after crush amputation (see Fig. 1) showing considerable forearm shortening of 12 cm (A). There is normal elbow function and very good prehensile capacity of the hand (B) with no significant cold intolerance (grade I result).

Crush amputation with extensive tissue damage

These amputations result from blunt high energy trauma. They show extensive tissue damage, which potentially may involve the whole amputated part. They are caused e.g. by gear drives, rollers, building machines and road traffic accidents. Extensive debridement with radical skeletal shortening is regularly required. The prognosis for survival is clearly less favourable than that for the first two categories.

Avulsion amputation

In these cases, the part is torn out rather than cut off or crushed. This results in severance of different structures at various levels. Tendons usually are torn out of their muscle bellies, and vessels and nerves may be damaged over a considerable distance. The prognosis is poor for survival and for the functional result as well. Extensive radical debridement and often long vascular grafts are necessary.

Tissue anoxia

Musculature is the tissue most sensitive to anoxia. At 20–25° C, rapid irreversible tissue damage will occur after 6 hours. In major replants with a large muscle bulk, reperfusion of musculature with substantial anoxic damage may – in the worst case – lead to post-ischaemia shock syndrome with multiple organ failure. Amputated parts with little or no muscle tissue, such as fingers, tolerate anoxia much better and can be reattached successfully even after 8–10 hours of anoxic time at room temperature. If finger segments are cooled, replantation is possible also after 20 or more hours. In clinical practice, cooling to about 4° C is by far the most important and effective measure for tissue preservation. In large amputated parts, cooling is most rapidly achieved by perfusion with cold solutions such as e.g. with University of Wisconsin solution, which also contains scavengers to neutralize toxic free-oxygen radicals (9, 24).

Level of amputation

As previously mentioned, there exists a fundamental difference between proximal amputations with important muscle mass in the amputated part and distal amputations with little or no musculature in the amputated segment. This applies not only to the risk of possible complications, but also to the quality of functional results. In proximal amputations, nerves must regenerate over long distances, and the prospect of highly selective reinnervation of motor and sensory components in the replanted part is poor. In this regard, distal amputations have a much better prognosis. Despite these facts, proximal replantations may be indicated, e.g. of an upper arm, even if there is no or little chance of recovery of useful prehensile function of the hand, if there is the possibility of regaining valuable function in the elbow joint. With active motion of the elbow joint, forearm and hand can often serve as a very useful lever arm. Even in exarticulation of the shoulder joint including the scapula, replantation may be considered for maintaining the contour of the shoulder, possibly with an amputation at the upper arm level at a later date that may facilitate subsequent prosthetic fitting (19). Above all, replantation is strongly indicated in cases where the function of the amputated segment cannot easily be substituted by the uninjured remaining parts. An example for this is thumb amputation proximal to the DIP joint. The thumb is an independent functional unit that cannot be substituted by any of the long fingers. Even in cases where restoration of protective sensibility cannot be expected, replantation is indicated, as sensibility can be restored at a later date to the thumb by one of the various types of neurovascular flap procedures. Especially in cases of finger amputations, the indication for replantation is greatly influenced by individual circumstances. In general, replantation of fingers in children is strongly indicated if near-normal bone growth can be anticipated.

One should bear in mind that return of function depends not only on good circulation and sensibility but also on a reasonable flexion arch of the replanted fingers. This is particularly important for the middle, ring and small fingers, as these are primarily involved in power grasping. An index finger on the other hand is primarily used in combination with the thumb for precision gripping, so that even with considerable loss of mobility it can still be very useful. The degree of flexion to be expected after replantation of the finger is largely determined by the level of amputation. Amputations distal to the insertions of the flexor digitorum superficialis tendon in the middle phalanx usually lead to excellent functional results because the active movement in the PIP and MP joints of the replanted finger will be normal. If there is no active movement in the distal joint, there will only be minimal functional loss.

However, if amputation is proximal to the insertion of the flexor digitorum superficialis tendon, the reattached fingers will have considerable loss of function in the PIP and frequently also in the MP joint. In establishing the indication for replantation of a finger, careful attention must therefore be paid to this critical level at the insertion of the flexor digitorum superficialis tendon. It also must be taken into consideration that cold intolerance of the replanted part can be extremely disturbing particularly in the second half of life. Also, the relatively high cost of replantation compared to what, for many patients, would only be a relatively minor loss of function must also be considered. A very conservative attitude is clearly indicated when a single finger has been amputated proximal to the insertion of the flexor digitorum superficialis, as the prognosis for a good range of motion is very poor. A stiff replanted finger may substantially compromise the global hand function (12).

If all four fingers have been amputated distal to the flexor digitorum superficialis insertion, good global function can also be achieved without replantation. The principles are therefore the same as those for single fingers amputated at this level.

If all four fingers have been amputated proximal to the flexor digitorum superficialis insertion, as many as possible should be reattached if these are suitable for replantation, giving priority to the index and middle fingers.

As a general rule, the best-preserved amputated segments should be replanted to the most important functional position irrespective of their original position (heterotopic replantation) (22). If there are multilevel injuries to the neurovascular structures, the prospect for a good functional recovery is usually poor and, particularly at the finger level, precludes replantation. The best results in upper extremity replantations are achieved in guillotine-type injuries at the level distal to the insertion of the flexor digitorum superficialis tendon for the long fingers, the thumb and in particular in hand amputations proximal but close to the wrist joint (14). Hand replantation at this level usually leads to amazingly good functional results. Therefore, this has recently been established as the level of hand transplantation (20).

Basic technical considerations

Based on the experience of more than 25 years, I would like to address the following points, which occasionally are not being paid appropriate attention (14–17): **Debridement** requires surgical experience and cannot be delegated to young, unexperienced colleagues. It is of paramount importance that all tissue not viable and well vascularized be removed including foreign bodies, if present, in conjunction with thorough irrigation. Debridement can take several hours. The work therefore should be started on the amputated part as soon as possible. In the course of debridement, the important anatomical structures for reconstruction are identified and tagged with fine sutures. In amputated fingers, it can be difficult to identify the dorsal veins. Compression of the pulp of the finger will slightly fill the veins with blood and thus facilitate identification, particularly if one looks for them from the inside of the subcutis. The time of anoxia should be reduced by using two surgical teams, one working on the amputated part and the other on the stump.

If the amputated part contains an important amount of musculature, continuous cooling of the part is necessary in order to minimize anoxic tissue damage.

The **sequence of repair** is largely determined by the anatomical topography pertaining to different levels of amputation, the need to restore circulation as quickly as possible, and by the fact that optimum vascular repair is only possible after skeletal fixation has been accomplished. Thereafter, the sequence of repair depends on the individual situation in each case. In general, reconstruction should start with the deep structures and proceed towards the surface.

If there has been prolonged anoxia, however, vascular repair must immediately follow skeletal fixation. At least one large vein must be anastomosed before restoring arterial circulation, especially in amputated parts of relatively large size. Doing this minimizes the otherwise considerable blood loss once arterial circulation is restored. Whenever possible, anastomosed vessels should not be reclamped in the further course.

In choosing the method of **skeletal fixation,** one must observe the following criteria: One should strive for as rigid a fixation as possible within the shortest possible time avoiding undue additional surgical trauma (size of the implants!) and achieving maximum bone contact. In finger replantations, the combination of K-wires with intraosseous wiring has proved its value and is now the method of choice (11). In the diaphyseal area of metacarpal bones, radius, ulna and humerus, tension band or dynamic compression plates are preferred. Screws are very useful in oblique amputations and in joint reconstruction at any level.

In replantations proximal to the wrist, insufficient bone shortening is one of the most common faults in replantation surgery. In restoration of skeletal axes, the most frequent error is incorrect rotational positioning, especially in finger replantation. When MP joints are destroyed, 40–60° range of motion can be achieved by primary Swanson implant arthroplasty (15, 16). If breakage of the silicon implants occurs in the later course, this does not necessarily mean replacement of the implants, as good function is still possible even with fractured implants. We are observing such as case now after more than 20 years.

For **vascular repairs,** a high level of skill is necessary that must be acquired by training in the microsurgical training laboratory. Only after such training should the surgeon be allowed to perform microvascular reconstruction in patients. As a general rule, arteries and veins should be repaired to the fullest possible extent. Relative inhibition of the venous return and temporary stoppage of lymph circulation are major factors in the development of postoperative oedema. It is amazing how little attention has been paid in the literature to the regeneration of lymphatic vessels after replantation (13, 21, 25). However, we know that lymph vessels do regenerate although some permanent stasis may result in most cases, fortunately not to such an extent that is clinically relevant (13). Vascular anastomoses should not be performed under undue tension. If there would be increased tension for direct vascular anastomoses, it is better to interpose an autologous vein graft, because the patency rate through two anastomoses under adequate tension is better than through one anastomosis that has been performed under increased tension.

Table 1. Functional results in relation to level of amputation (38 cases, Zurich, 1981–98, min. 2 years follow-up).

Level of amputation	*n*	Grades I + II	Grade III	Grade IV
Shoulder	1	0 (0 %)	0 (0 %)	1 (100 %)
Arm	3	0 (0 %)	3 (100 %)	0 (0 %)
Proximal forearm	8	1 (12 %)	7 (88 %)	0 (0 %)
Distal forearm	10	9 (90 %)	1 (10 %)	0 (0 %)
Wrist (carpus)	7	6 (86 %)	1 (16 %)	0 (0 %)
Palm	9	6 (67 %)	3 (33 %)	0 (0 %)
Total	38	22 (60 %)	15 (38 %)	1 (2 %)

Table 2. Functional results in relation to level of amputation (182 cases, Shanghai, Louisville, Zurich, 1981, min. 2 years follow-up).

Level of amputation	*n*	Grades I + II	Grade III	Grade IV
Shoulder	3	0 (0 %)	1 (33 %)	2 (67 %)
Arm	26	9 (35 %)	17 (65 %)	0 (0 %)
Proximal forearm	20	8 (40 %)	7 (35 %)	5 (25 %)
Distal forearm	48	38 (79 %)	10 (21 %)	0 (0 %)
Wrist (carpus)	31	25 (81 %)	6 (19 %)	0 (0 %)
Palm	54	32 (60 %)	18 (33 %)	4 (7 %)
Total	182	112 (62 %)	59 (32 %)	11 (6 %)

Table 3. Functional results in relation to level of amputation (220 cases, Shanghai, Louisville, Zurich 1981 and Zurich 1980–98, min. 2 years follow-up).

Level of amputation	*n*	Grades I + II	Grade III	Grade IV
Shoulder	4	0 (0 %)	0 (0 %)	4 (100 %)
Arm	29	9 (31 %)	20 (69 %)	0 (0 %)
Proximal forearm	28	9 (32 %)	14 (50 %)	5 (18 %)
Distal forearm	58	47 (81 %)	11 (19 %)	0 (0 %)
Wrist (carpus)	38	31 (82 %)	7 (18 %)	0 (0 %)
Palm	63	38 (60 %)	21 (33 %)	4 (7 %)
Total	220	134 (61 %)	73 (33 %)	13 (6 %)

The quality of **nerve repair** and subsequent nerve regeneration largely determines the functional result of a replanted extremity. The latest advances in techniques and strategy should be applied to nerve reconstruction in replantation as elsewhere in peripheral nerve surgery. In avulsion amputations, this may also include endto- side nerve junctures if the corresponding proximal stump cannot be used.

Optimum **wound closure** depends very much on the extent of bone shortening.

With replantation of the forearm or upper arm, it is of little importance to the patient e.g. if the bones have been shortened by 3 cm or 5 cm, but the extra 2 cm can be of vital importance for optimal wound closure, and even determine whether the replantation will be successful or not. Before the wounds are closed, one should think of the possibility of subsequent compartment syndrome. In temporary denervated replanted extremities, no clinical signs of compartment syndrome will become obvious in the postoperative course. Therefore, initial fasciotomy should be considered and performed in all doubtful situations (16). In trauma surgery, I have never seen an important functional impairment due to a potentially unnecessary fasciotomy, but rather many catastrophes because fasciotomy was not performed early enough.

Results of major upper extremity replantation

For the purpose of this presentation, we focus on so-called major replantations, i.e. amputations through the palm and proximal to this level.

In full awareness of the difficulties inherent in expressing numerically the degree of function achieved as a result of replantation, we still classify our cases according to the simple criteria established by *Chen* et al. (3).

In *Chen*'s system, the results are classified into four grades, based on the analysis of four parameters: (I) ability to work, (II) range of joint motion, (III) recovery of sensibility, and (IV) muscle power, each rated on a scale of 1 to 5.

Grade I

1. Patient able to resume original occupation with a major contribution made by the replanted part.
2. Joint mobility at least 60 % of normal.
3. Sensibility largely restored, and no excessive cold intolerance.
4. Muscle power rated 4–5.

Grade II

1. Patient able to take up gainful employment but not original occupation with a major contribution made by the replanted part.
2. Joint mobility at least 40 % of normal.
3. Sensibility largely restored to the area of distribution of the median and ulnar nerves, respectively, and no excessive cold intolerance.
4. Muscle power rated 3–4.

Grade III

1. Patient independent in activities of daily life.
2. Joint mobility at least 30 % of normal.
3. Poor but still useful restoration of sensibility, e.g. in the median or ulnar area only, or nearly protective sensibility in both the median and ulnar areas.
4. Muscle power rated 3.

Grade IV

Survival of the replanted part with no appreciable useful function.

Roughly summarized, the four grades could be defined as follows:

- Grade I: excellent
- Grade II: good
- Grade III: moderate but satisfactory and worthwhile
- Grade IV: bad, not worthwhile

In 1981, the replantation centres of Shanghai, Louisville and Zurich analysed their first series of long-term functional results (i.e. 2 or more years after amputation). The analysis of the compiled data from Asia, Europe and the United States, which were consistent in format, has shown that the independent experiences of these replantation centres were remarkably similar, in fact practically identical (3).

This analysis of 182 cases clearly showed, already 20 years ago, that, with regard to the level of amputation, by far the most rewarding results could be achieved after replantation at the level of the distal forearm or wrist (3, 14, 23). These results are shown in Table 1. If we compare the analysis of 38 patients who underwent replantation in Zurich between 1981 and 1998, these results fall precisely into the common pattern already established in 1981 (Table 2).

Therefore, it is justified to add the most recent 38 cases to the results from 1981. This gives an overview of functional results related to level of amputation in 220 cases of major upper extremity replantations (Table 3).

Conclusions

Upper extremity replantation has definitely proved its value as a most successful method of treatment if the guidelines outlined for indications and surgical strategies are observed.

Especially in major replantations, in almost all cases a substantial positive socioeconomic impact is achieved. By far the best results can be anticipated in proximal but close to the wrist amputations.

The high level of success and quality of results had in fact already been achieved 20 years ago. Since then, no really significant changes can be recognized, except for the benefit of security measures in industrial settings and their impact on the number of cases, which significantly decreased, and on the pattern of the type of amputation injuries.

As replantation surgery has been a pacemaker for free microvascular composite tissue transplantation, at this time hand transplantation is about to become a pacemaker for free microvascular composite tissue allotransplantation (20).

The development of microsurgical techniques has literally revolutionized the possibilities of reconstructive surgery during the past 30 years. This revolution will go on and will open unexpected horizons because the control of immune reactions associated with allotransplantation will be improved.

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